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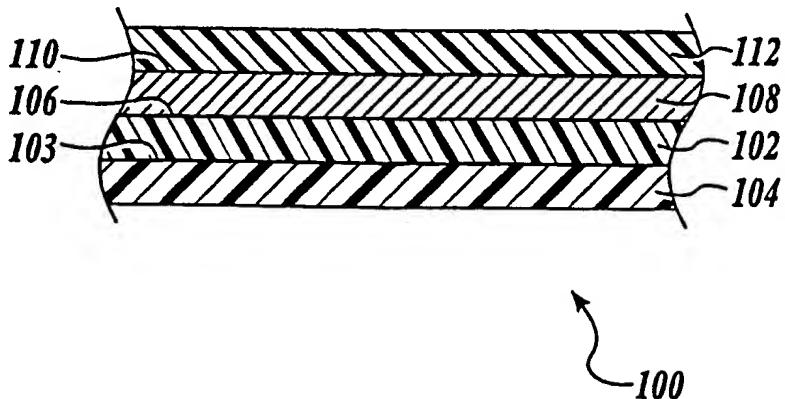
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(54) Title: METHOD FOR ADHERING LAMINATE STRUCTURES

(57) Abstract

It has been discovered that a combination of a reactive compound in the monomer in combination with a contact surface activating plasma achieves maximum lamination strength for a polymer/second layer laminate for vacuum lamination. This is true whether the second layer is placed upon the polymer layer or whether the monomer is placed upon the second layer then polymerized as the polymer in a vacuum.



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## METHOD FOR ADHERING LAMINATE STRUCTURES

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### FIELD OF THE INVENTION

The present invention relates to a method and apparatus for adhering laminate structures. More specifically, the invention relates to a combination of a reactive compound within a monomer and a surface activating plasma to provide an activated surface for adhering a second laminate layer via vacuum deposition to the polymer layer.

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### BACKGROUND OF THE INVENTION

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In many industrial processes non-polymer thin films including but not limited to metals, metal-oxides, semiconductors and combinations thereof are placed on polymer thin films in the form of substrates and/or layers. These thin film combinations are prepared *in-situ* by a number of methods including but not limited to extrusion, flash-evaporation, spraying, blading, plasma enhanced chemical vapor deposition (PECVD), sputtering, evaporation and combinations thereof. The adhesion of these thin film combinations is commonly variable depending upon substrate, deposition method and materials deposited. Therefore treatments such as plasma discharges and/or irradiation with electrons, ultraviolet or laser are routinely employed to activate either the thin film or the polymeric surface or both to promote improved adhesion. However, these methods provide variable levels of strength adhesion and for some material combinations, very low or no strength adhesion based upon a tape pull test.

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Accordingly there is a need for a method and apparatus to provide greater lamination strength for laminate structures as well as less variability between alternative laminations.

## SUMMARY OF THE INVENTION

It has been discovered that a combination of a reactive compound in the monomer in combination with a contact surface activating plasma achieves maximum lamination strength for a laminate. This is true whether the second layer is placed upon the polymer layer or whether the monomer is placed upon the second layer then polymerized as the polymer when the contact is made with vacuum deposition.

It is an object of the present invention to achieve superior adhesion between a polymer and a second layer by adding a reactive compound to the polymer and by activating a contact surface with a plasma in a vacuum.

The subject matter of the present invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. However, both the organization and method of operation, together with further advantages and objects thereof, may best be understood by reference to the following description taken in connection with accompanying drawings wherein like reference characters refer to like elements.

## BRIEF DESCRIPTION OF THE DRAWINGS

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FIGURE is a cross section of a reflector made and tested as Example 1.

## DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

25 The present invention is a method and apparatus for of adhering a polymer layer to a second layer which rely upon a combination of

- (a) a reactive compound in the polymer layer;
- (b) a contact surface selected from the group consisting of a polymer contact surface, a second layer contact surface and combinations thereof exposed to a surface activating plasma and providing an activated contact surface; and

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(c) contacting the second layer contact surface to the polymer contact surface in a vacuum, one or the other or both of which is the activated contact surface, thereby adhering the second layer with the polymer layer.

5 The polymer contains an additive that provides one side of a chemical hook that connects with the species provided from the plasma on the second layer contact surface as the other side of the chemical hook. Thus, the adhesion is achieved by selection of additive/plasma species combinations. More specifically, the connection is achieved with a donor acceptor reaction, preferably a base-acid

10 reaction. For example silicone with a plasma containing oxygen and hydrogen provides OH groups that bind to the silicone. Amine functionalities may be useful for other applications. It is preferred that the acid and base be organic. Preferred organic acids contain a CO= structure, for example carboxylic acids including formic acid, acetic acid, oxalic acid butyric acid; ketones; esters; amino

15 acids; aldehydes; and combinations thereof. Preferred base has OH, but may have NH or SH groups, for example amines, mercaptans and combinations thereof.

Several combinations are possible. One combination is by adding the reactive compound to a monomer as a monomer mixture. The monomer mixture

20 may be placed on a substrate via any method including but not limited to extrusion, flash-evaporation, spraying, blading and combinations thereof then polymerized to provide a polymer surface for receiving the non-polymer. Alternatively, the monomer mixture may be placed upon the second layer then

25 polymerized in-situ on the second layer. In either case, the solid surface is plasma treated prior to contact with the other material.

A vacuum is defined herein as having a pressure less than atmospheric pressure wherein processes including but not limited to sputtering, flash evaporation, plasma enhanced chemical vapor deposition, evaporation and combinations thereof may be conducted.

30 In a preferred embodiment, the monomer is acrylate or methacrylate. Other monomers are possible including but not limited to allyls (double bond), alkynes (triple bond) for example phenyl acetylene. For acrylate or methacrylate

monomer/polymer, the reactive compound may be acrylated silicone. The amount of reactive compound must be sufficient to provide enough reactive material at a surface to provide a strong bond. It has been found that an effective amount of reactive compound is less than about 10 wt%.

5        The second layer may be another layer of the same polymer composition as the polymer layer. Alternatively, the second layer may be a metal, ceramic or combination thereof. Metal includes but is not limited to silver, copper, nickel, aluminum, iron, and combinations thereof. Ceramic includes metal oxides, metal nitrides, silicon oxides, metal carbides and combinations thereof.

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When the additive contains silicone and the plasma contains hydrogen and oxygen, OH groups are formed. The surface activating plasma may be a single compound plasma for example water. However, in some cases water is difficult to maintain as a plasma so a ballast gas may be desired, for example 15 argon. Because it has been found that a combination of hydrogen and oxygen provides good surface activation, a two-compound plasma of hydrogen and oxygen may also be used for forming the OH groups. The particular combination of plasma gases is specific to the additive and to the second contact surface. For a polymer surface, an argon/water plasma is effective to activate the polymer 20 surface when silicone is the additive. For a metallic non-polymer surface, an oxygen/hydrogen plasma has the advantage of avoiding water condensation in the delivery system.

The stoichiometric ratio of oxygen to hydrogen is 1:1. Because it is desired to minimize the amount of gas in the system, it is preferred to operate at 25 or near the stoichiometric amount.

When using a substrate containing oxygen atoms, for example PET, to receive a monomer mixture having silicone therein, it is sufficient that the substrate be plasma treated with a low-intensity argon plasma because the argon in the plasma activate the oxygen in the substrate.

**EXAMPLE 1**

An experiment was conducted to demonstrate adhesion of silver with polymer with and without the elements of the present invention.

5 Silver reflectors having a laminate composition of PET substrate, flash evaporated acrylate layer 1, silver layer, and flash evaporated acrylate layer 2 were made.

A silver reflector made with no reactive compound and no plasma surface treatment had such poor adhesion that tape pull tests resulted in complete delamination or removal of the top polymer layer from the silver layer.

10 In a subsequent pull test, the silver came off of the bottom polymer layer.

A silver reflector made with plasma treated surfaces gave the same delamination/removal results with the pull test as the untreated surfaces.

15 A silver reflector made with reactive compound added to the monomer/polymer gave the same delamination/removal results as the untreated surfaces.

A silver reflector 100 was made according to the present invention (FIGURE) with 5 wt% acrylated silicone (Ebecryl 350) as the reactive compound in an acrylate polymer 102. In addition, a low intensity argon plasma was used to treat the surface 103 of a PET substrate 104 upon which the first monomer 20 layer was flash evaporated and condensed and subsequently polymerized 102. The polymerized surface 106 was exposed to an argon/water plasma for surface activation prior to putting down the silver layer 108 by sputtering. The top silver surface 110 was further activated with a oxygen/hydrogen plasma with a ratio of oxygen to hydrogen of 1:1. A second monomer mixture layer 112 was flash 25 evaporated and condensed onto the activated silver layer 110. Tape pull tests, with or without razor cross hatching, resulted in no delamination or removal of any layer.

**CLOSURE**

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While a preferred embodiment of the present invention has been shown and described, it will be apparent to those skilled in the art that many changes

and modifications may be made without departing from the invention in its broader aspects. The appended claims are therefore intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

## CLAIMS

We claim:

- 5        1. A method of adhering a polymer layer to a second layer, comprising the steps of:
  - (a) providing a reactive compound in said polymer layer;
  - (b) exposing a contact surface selected from the group consisting of a polymer contact surface, a second layer contact surface and combinations thereof to a surface activating plasma and providing an activated contact surface; and
  - (c) contacting said second layer contact surface to said polymer contact surface in a vacuum, one or the other or both of which is said activated contact surface, thereby adhering the second layer with the polymer layer.
- 20        2. The method as recited in claim 1, wherein said providing is by adding said reactive compound to a monomer as a monomer mixture.
- 20        3. The method as recited in claim 2, wherein said polymer surface is formed by polymerizing said monomer mixture.
- 25        4. The method as recited in claim 2, wherein said contacting is by placing said monomer mixture onto said non-polymer followed by polymerization of said monomer mixture, and wherein said activated surface is said second layer contact surface.
- 30        5. The method as recited in claim 1, wherein said reactive compound is acrylated silicone.
- 30        6. The method as recited in claim 5, wherein said polymer contact surface is activated with an argon/water plasma.

7. The method as recited in claim 5, wherein said second layer contact surface is silver.

5 8. The method as recited in claim 7 wherein said surface activating plasma is selected from the group consisting of oxygen/hydrogen, water, and combinations thereof.

9. The method as recited in claim 8 wherein said surface activating 10 plasma includes a noble gas.

10. The method as recited in claim 9, wherein said noble gas is argon.

15 11. The method as recited in claim 1, wherein said contacting is selected from the group consisting of sputtering, flash evaporation, plasma enhanced chemical vapor deposition, evaporation and combinations thereof.

12. A method of adhering a polymer to a second layer, comprising the 20 steps of:

(a) adding a reactive compound to a monomer as a monomer mixture and polymerizing the monomer mixture to said polymer layer;

(b) activating said reactive compound at a surface of said polymer by exposing said surface to a polymer surface activating plasma, and 25 providing an activated polymer surface; and

(c) contacting said activated polymer surface with said second layer whereupon bonding adheres said second layer to said polymer.

13. The method as recited in claim 12, wherein said reactive 30 compound is acrylated silicone.

14. The method as recited in claim 12, wherein said polymer surface activating plasma is an argon/water plasma.

15. A method of adhering a second layer to a polymer, comprising the  
5 steps of:

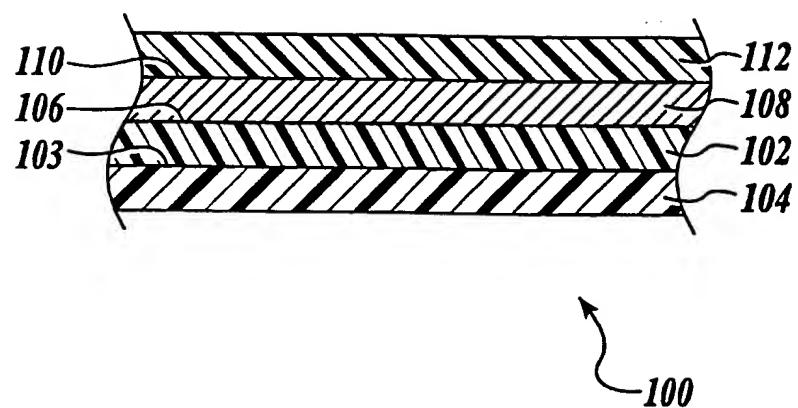
- (a) activating a surface of said second layer by exposing said surface to a second layer surface activating plasma, and providing an activated surface;
- 10 (b) adding a reactive compound to a monomer as a monomer mixture and contacting said monomer mixture with said activated surface; and
- (c) polymerizing said monomer mixture

16. The method as recited in claim 15, wherein said reactive compound is acrylated silicone.

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17. The method as recited in claim 15, wherein said second layer surface activating plasma is an oxygen/hydrogen plasma.

18. The method as recited in claim 15, wherein said contacting is  
20 selected from the group consisting of sputtering, flash evaporation, plasma enhanced chemical vapor deposition, evaporation and combinations thereof.



## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 00/03362

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B05D7/02 B05D7/04 B32B7/10 B32B31/12 C08J5/12  
C08J7/04 B32B31/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 B05D B32B C08J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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